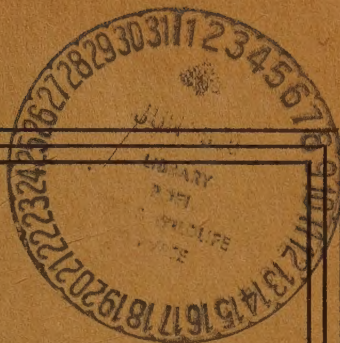


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UNION OF SOUTH AFRICA

DEPARTMENT OF COMMERCE AND INDUSTRIES

DIVISION OF FISHERIES

INVESTIGATIONAL REPORT No. 17

THE SOUTH AFRICAN PILCHARD
(Sardinops ocellata)

**PLANKTON STUDIES IN AND AROUND
ST. HELENA BAY, 1950-51**

BY

B. v. D. de Jager, M.Sc.

(Professional Officer)

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1. SUMMARY.

This paper is a further contribution to the series on the life history of the South African pilchard, *Sardinops ocellata* (Pappe).

After the introduction and discussion of the problem and methods, an attempt is made to show the relationship between the abundance and seasonal variation of the plankton, and the chemical and physical factors such as temperature, salinity and phosphate content of the sea in the area where the pilchard research was carried out.

Then follows an analysis of the data obtained from night sampling stations, in order to illustrate the relation between the variation in abundance of plankton and the feeding habits of the pilchard.

A list of zooplankton and phytoplankton genera recorded during the period April 1950-March 1951 is given. Brief reference is made to the occurrence and distribution of non-edible plankton forms such as Salps, Doliolids, Foraminifera, etc., and to the occurrence of certain organisms found in association with pilchard eggs..

2. INTRODUCTION.

The pilchard research programme began in April, 1950, with the vessels R.S. *Africana II*, R.V. *Schipa* and P.B. *Palinurus* working a network of stations offshore and inshore in the neighbourhood of the commercial fishing area of St. Helena Bay.

One of the aspects of this programme was a study of the abundance and seasonal variation of the plankton, and the conditions under which it lives in relation to the—

- (a) early life history of the pilchard;
- (b) organisms serving as food for the pilchard;
- (c) general productivity of the sea;
- (d) species which might indicate water movements and currents;
- (e) biology of other commercial species of fish.

The eggs and larvae of the pilchard appear as temporary members of the plankton. The location of the major spawning areas of the pilchard is therefore very important in relation to future attempts to forecast the commercial catch. Moreover, the recent collapse of the Californian pilchard fishery has shown the extreme importance of assessing the extent of spawning together with the rate of survival of larvae, in order to form an idea of the renewal of the fish stock. Such an assessment is essential for finding a sound

basis of conservation of the South African pilchard resource.

The vast numbers of pilchards found off the west coast of the Union are dependent on an adequate supply of food and since pilchards are plankton feeders, the assessment of the available zooplankton and phytoplankton populations is of vital importance. It must be remembered also that the abundance of phytoplankton and zooplankton is indicative of the general productivity of the area in which the commercial fishery takes place.

Transient and other plankton forms such as the eggs and larvae of fishes and invertebrates, for instance the phyllosomata of the rock lobster, often assist in the explanation of complex hydrological conditions, such as are for example present off our West coast. Planktological data are also necessary in researches into the biology of other commercially important species such as the Stockfish (*Merluccius capensis*) and the Cape Rock Lobster (*Jasus lalandii*).

The term "edible plankton" used in this report embraces only those plankton forms which are important as sources of food for fishes. Forms such as Salps, Doliolids and Hydromedusae are regarded as non-edible.

Planktological data collected earlier by expeditions such as those undertaken by the *Discovery*, *Discovery II*, *Meteor*, *Dana*, etc., were of considerable assistance in problems of identification in the present study, but, not being of a continuous nature, these data could not be used in relation to seasonal variation.

In the early stages of the present investigations the plankton research work was under the direction of Dr. S. G. Gibbons, formerly Professional Officer in this Division, to whom the writer is indebted for instruction in methods of plankton collection and research.

3. METHODS.

All three vessels of the Division of Fisheries were engaged in the pilchard research scheme, and each was responsible for the collection of plankton samples.

R.S. *Africana II* carried out all the work related to a series of offshore routine stations worked twice a month. The two smaller vessels of the Division, viz. R.V. *Schipa* and P.B. *Palinurus*, worked the inshore series of stations, as well as the night stations (see under 4, Research Areas).

All plankton nets used in this work were of the standard types used by R.R.S. *Discovery II*.

A full description of these, together with the methods of their operation, may be found in Discovery Reports (Kemp, Hardy and Mackintosh, 1929).

The procedure at the routine stations occupied by R.S. *Africana II* was as follows:—

(1) *Planktological*.

- (a) A N50V plankton tow-net haul from 100 metres (or near the bottom if the depth was less) was made to the surface at selected stations;
- (b) a N70V plankton tow-net haul from 100 metres (or near the bottom if the depth was less) to the surface was made at each station;
- (c) a N100H plankton tow-net haul at 0 metres for 10 minutes was made at each station;
- (d) a N200YFT haul was made at selected stations—usage discontinued at an early stage owing to poor results.

(2) *Hydrological*.

- (a) A temperature and a water sample were taken at the depths 0, 10, 20, 30, 40, 50, 60, 80, 100, 125, 150, 175, 200, 250, 300, 400 metres at each station according to depth;
- (b) a bathythermograph record down to 270 metres (or to near the bottom if the depth was less) was taken at each station;
- (c) a continuous thermographic record of the surface temperature was taken throughout the routine cruise.

(3) *Meteorological*.

Weather observations were taken at each station and four-hourly weather observations throughout the routine cruise.

The collected samples were treated as follows:

- (a) The settled volumes of the plankton catches were measured at every station after inedible species such as Salps, Doliolids and Medusae had been removed;
- (b) the catches obtained from the N50V nets were preserved in 10 per cent neutral formalin, labelled and brought ashore for examination;
- (c) accurate fractional or split samples were obtained by means of a plankton-sample splitter (see page 20, California Co-

operative Sardine Research Program, Progress Report, 1950), preserved and labelled for detailed examination ashore;

- (d) the initial examination of the plankton catches was made at sea with the aid of a siphon apparatus (Gibbons, 1952), which enabled one to examine the samples under a dissecting microscope even when the ship had lively movement;
- (e) a special plankton log sheet was used to record the details of the plankton genera, as well as information regarding the surface temperature, the position of the catch and the gear used;
- (f) fish eggs and larvae present in the plankton catches were extracted, and the eggs and larvae preserved in 2 per cent and 10 per cent neutral formalin respectively;
- (g) whenever clupeoid eggs were found in sufficient numbers, the whole sample was preserved, labelled and brought ashore to be identified, counted and measured;
- (h) whenever horizontal and vertical plankton nets were used, indicators measuring the angle of stray were used in order to calculate the actual depth of the net (see California Co-operative Sardine Research Program, Progress Report, 1950).

The following procedure was carried out by the smaller vessels at the inshore stations:—

(i) *Planktological*.

- (a) A N50H plankton tow-net haul at 0 metres for 10 minutes was made at selected stations;
- (b) a N70H plankton tow-net haul at 0 metres for 10 minutes was made at each station;

(ii) *Hydrological*.

A surface temperature was taken at each station;

(iii) *Meteorological*.

Weather observations were taken at each station.

The plankton samples collected by the small vessels were preserved, labelled and taken ashore for examination by the resident biologist either at Stompneus or Lambert's Bay. The shore biologists extracted eggs and larvae, and also took aliquot samples from plankton catches for detailed examination at the headquarters laboratories.

PLANKTONLOG. PLANKTON LOG.

N.N./C.I. 358

195.....

Stasie No. Posisie .
Station No. Position
Type net. Duur. Diepte .
Type of net Duration Depth
Tyd. Lig of donker .
Time Light or dark
Oppervlaktetemperatuur .
Surface temperature
Volume van afgesakte plankton in c.c.
Settled volume in c.c.
Algemene opmerkings
General remarks

Vernaamste genera min of meer in orde van voorkoms :—
Principal genera in approximate order of prevalence :—

(a) SOÖPLANKTON :— ZOOPLANKTON :—

1	13	25
2	14	26
3	15	27
4	16	28
5	17	29
6	18	30
7	19	31
8	20	32
9	21	33
10	22	34
11	23	35
12	24	36

(b) FITOPLANKTON. (indien aanwesig) PHYTOPLANKTON. (if present)

1	7	13
2	8	14
3	9	15
4	10	16
5	11	17
6	12	18

Besondere opmerkings oor soorte.
Particular remarks on species.

Trigsurvey, 1954.

TEXT FIG. 1
PLANKTON LOG SHEET.

Government Printer, 1954.

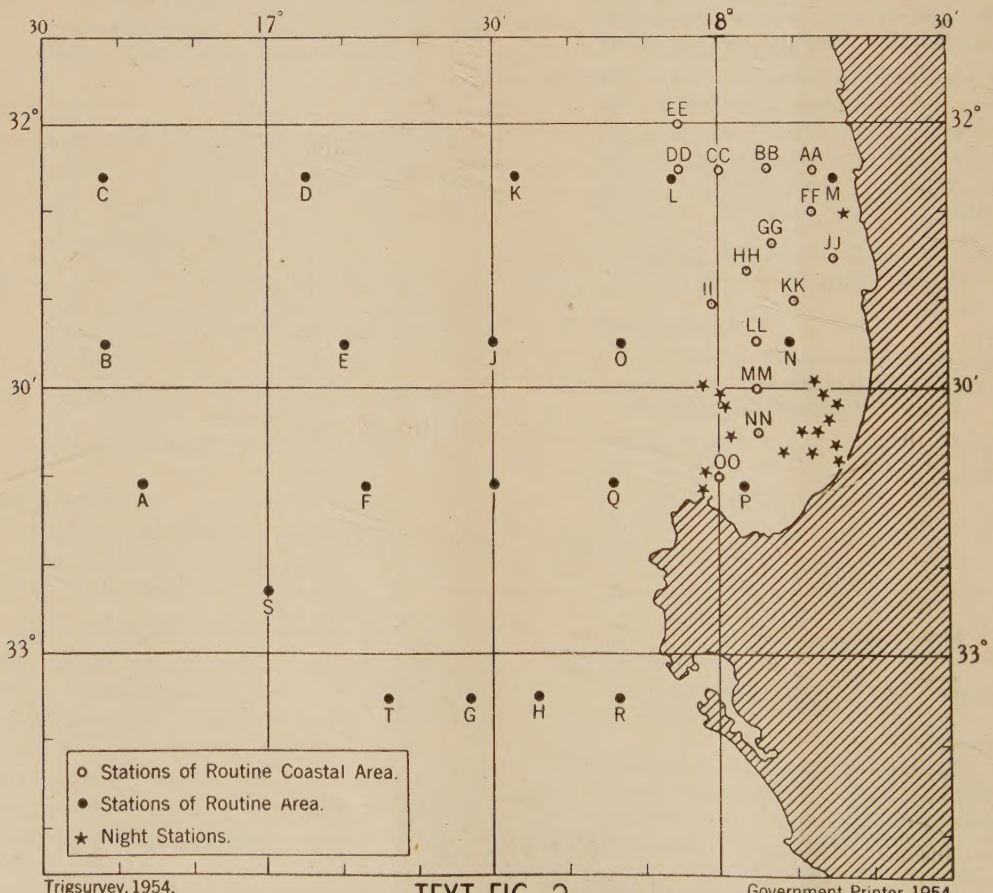
4. RESEARCH AREAS

The data used in this report were obtained from three groups of stations:—

- (a) Entirely coastal, consisting of 15 stations worked on an average of three times a month by either P.B. *Palinurus* or R.V. *Schipa*. The area covered by these stations was approximately 900 square miles and stretched from Stompneus in the south to Lambert's Bay in the north. It extended seaward from the coast for a distance of twenty miles in the north and about four to five miles off Stompneus in the south. The 15 routine stations in this area are shown in Fig. 2. In the present report this area is referred to as the *routine coastal area*.
- (b) An outer network of 18 (and later 20) stations worked by R.S. *Africana II* on an average of twice a month in the area

bounded by Salhanha Bay in the south and Lambert's Bay in the north, and extending seawards some 80 miles from the coast in the north and 40 miles in the south. The area covered by this group of stations (see Fig. 2) was approximately 4,000 square miles and it is referred to in the report as the *routine offshore area*.

- (c) Night sampling stations, worked in the coastal area fished by the commercial boats. At each of these stations a sample of fish was taken from the catch of the commercial boat in the act of brailing, a plankton tow-net haul was made in the immediate vicinity of the site of the catch and the standard meteorological observations were recorded. The stations were mostly close to Stompneus, as shown in Fig. 2. This area is referred to in the report as the *commercial catch area*.



Trigsurvey, 1954.

TEXT FIG. 2
RESEARCH AREAS.

Government Printer, 1954.

5. THE RELATIONSHIP BETWEEN PLANKTON VOLUMES AND CERTAIN HYDROLOGICAL FACTORS.

In the course of the study of the abundance and seasonal variation of edible zooplankton and phytoplankton, data on the environmental conditions of the seawater in the areas of research were collected. From these data the relationship between the seasonal variation in the abundance of plankton and the corresponding fluctuations in certain hydrological factors can be shown.

The data for settled volumes, salinity, temperature and phosphate content which were collected by R.S. *Africana II* during the first year's investigations, i.e. from April, 1950—March, 1951, were treated on an annual basis. A more detailed analysis was carried out, however, of the data collected by the smaller ships in the inshore area. This was done as (a) it was considered necessary to have more detailed knowledge of the environmental conditions existing in the area where the actual commercial fishing of pilchards took place, and (b) the study of the graphical data for the routine offshore area revealed the importance of the routine coastal area.

(a) ROUTINE OFFSHORE AREA.

The settled volumes of edible plankton were obtained from hauls made with vertical nets from 100 metres or less, depending on the depth, to the surface. Measurements of volumes were taken after the non-edible forms such as Salps, Medusae, etc., had been removed.

Although the settled volumes of edible plankton taken in this way are not an entirely true reflection of plankton abundance, they are indicative of seasonal variation. (Later, when the plankton collections have been examined qualitatively and quantitatively, it will be possible to correlate the findings of this first year's work with those of successive years.) Means of the settled volumes of all the samples taken at each station over a period of a year was taken. These averages were plotted on a chart (see Fig. 3).

The difference between the volumes at the inner and outer stations of the routine offshore area was striking. There was a marked decrease in the concentration of plankton from the coast seawards. The average settled volume per station

in inshore waters was 43.3 c.c. compared with 12.2 c.c. in offshore waters. During 1950 phytoplankton was never abundant offshore, whilst zooplankton often contained inedible oceanic forms. From a quantitative point of view it is clear that the huge shoals of pilchards and maasbankers frequenting St. Helena Bay had more than an adequate food supply in these inshore waters.

The temperature, salinity and phosphate content estimations of the 0-50 metre layer were averaged for each station throughout the year and plotted on charts (see Figs. 4 and 5). It is at once evident from Fig. 3 to 5 that certain marked trends were common to both the plankton-abundance and the hydrological data. Thus temperature and salinity decreased towards the shore, whilst phosphate content and settled volume increased. The average salinity and temperature of the 0-50 metre layer for the inshore stations were 34.84‰ and 12.08°C . respectively, whilst the respective values for the offshore stations were 35.17‰ and 15.16°C .

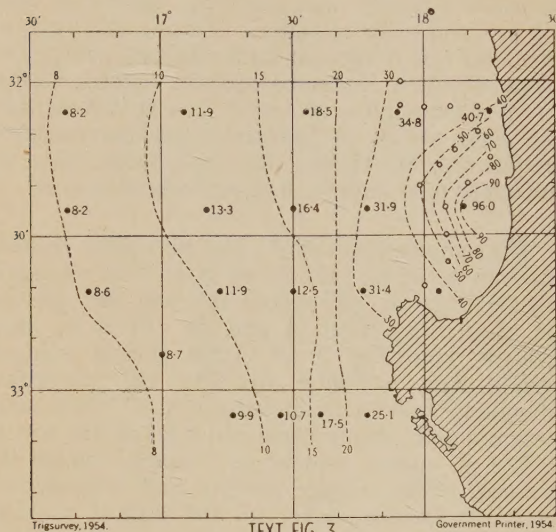
During the autumn and winter seasons of 1950 there were unfortunately no phosphate content data available, but in the corresponding seasons of 1951 the data clearly showed the annual phosphate content to be higher inshore than offshore.

Taken on an annual basis the coastal stations of the routine offshore area were characterized by—

- (i) high inorganic phosphate content;
- (ii) low salinity;
- (iii) low temperature;
- (iv) high plankton settled volume.

The values of salinity, temperature and phosphate content of the 0-50 metre layer, averaged for the whole area (all stations) on a seasonal basis, are shown in Table I on page 9. The table also records the salinity, temperature and phosphate content of the surface layer similarly averaged, together with the average seasonal values of settled plankton volumes for the 100-0 metre layer.

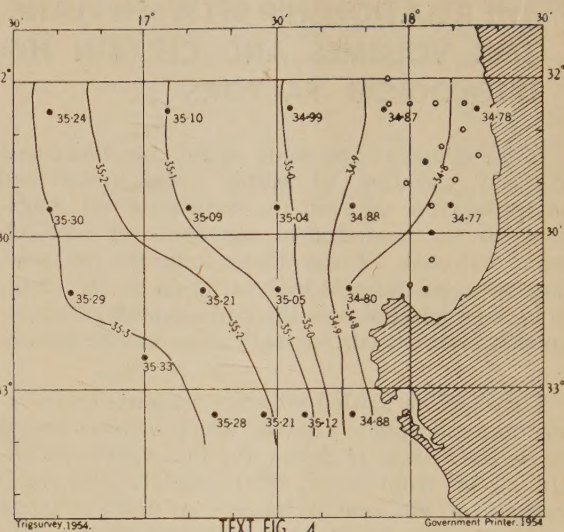
The annual range of the surface temperature in the routine offshore area was small and changes in temperature were gradual. The temperature



TEXT FIG. 3

PLANKTON DISTRIBUTION CHART

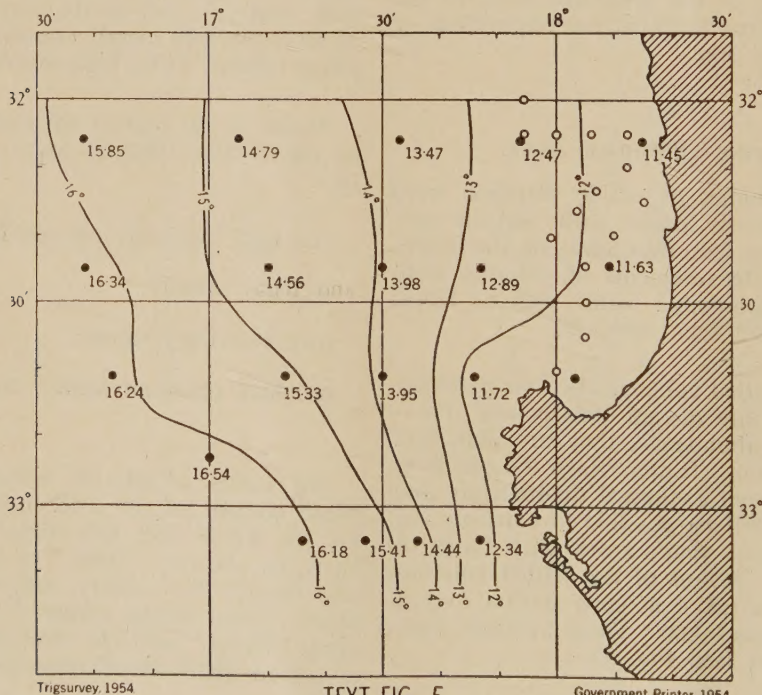
AVERAGE SETTLED VOLUMES OF EDIBLE PLANKTON (ZOO- AND PHYTOPLANKTON)
NET N 70 V 100-M. (OVER WHOLE YEAR IN C.C.)



TEXT FIG. 4

SALINITY CHART.

AVERAGE SALINITIES 0-50 M. (OVER WHOLE YEAR)



TEXT FIG. 5

TEMPERATURE CHART.

AVERAGE TEMPERATURES 0-50 M. (OVER WHOLE YEAR)

range of the 0-50 metre layer was even smaller than that of the surface layer. The total annual range for the surface was 0.67°C ., whilst the annual range for the 0-50 metre layer amounted

to only 0.42°C . However, the range of temperature between the grouped offshore and inshore stations was 3.08°C . Surface temperatures were lowest in winter and highest in summer and

TABLE I.

Season.	T $^{\circ}\text{C}$.		Salinity ‰.		Phosphate Content, mg-atom P/m ^{3} .		Settled Volumes in c.c.
	Surface.	0-50 M.	Surface.	0-50 M.	Surface.	0-50 M.	100-0 M.
Autumn, 1950.....	15.73*	14.31*	35.13*	35.07*	0.68†	1.03†	14.4
Winter, 1950.....	14.99*	14.39*	35.14*	35.10*	0.75†	0.95†	11.3
Spring, 1950.....	15.49	14.37	35.17	35.14	0.53	0.79	15.7
Summer, 1950-51....	15.67	13.95	34.99	34.98	0.64	0.95	28.7

* Including interpolated values for S. and T.

† 1951 results.

autumn, although it must be emphasized that the annual range was small. In the 0-50 metre layer the lowest temperatures were recorded in the summer and autumn seasons, whilst the highest temperatures were observed in spring and winter. During summer and autumn, when surface temperatures were relatively high, the temperature of the 0-50 metre layer was low.

Various physical conditions may contribute to create these differences between the surface and 0-50 metre layer. In late spring and summer strong southerly winds caused upwelling towards the coast. The presence of upwelled water was clearly shown by the lower temperature of the 0-50 metre layer during summer and autumn. The upward trend of the surface temperatures during summer was caused by increased absorption of solar radiation, which tended to counteract the effect of upwelling in the surface layer. During winter when solar radiation was greatly reduced

and the area was often lashed by strong north-westerly gales, the surface temperatures were lowest.

The temperatures of the 0-50 metre layer were high in winter and spring, these being the seasons when the frequency of southerly winds was reduced. (The effects of local physical conditions on temperatures and other factors are discussed under the routine coastal area.)

The salinities of the surface and the 0-50 metre layer showed similar variations throughout the year. However, the actual values of the salinity for the surface were slightly higher than those of the 0-50 metre layer.

A close relationship between the temperature and salinity of the 0-50 metre layer was evident. Maximum salinity was recorded in spring when the temperature of the 0-50 metre layer was

highest, whilst the lowest values of both salinity and temperature were registered in summer. The decrease in salinity and temperature in summer was probably caused by increased upwelling during that season.

As already mentioned, there were no phosphate data available for the autumn and winter seasons of 1950. In order to try to give a seasonal picture, the values for the corresponding seasons of 1951 were taken and inserted in Table I. These values showed a marked decrease in inorganic phosphate in the 0-50 metre layer from autumn to winter, with the lowest value in spring. This decrease may be directly related to the phytoplankton bloom occurring during spring. During the summer season a rapid regeneration of phosphate appeared to have taken place. In the season when maximum upwelling takes place, i.e. summer, the phosphate content was higher than in spring. Whenever phosphate was low in spring the salinity and temperature of the 0-50 metre layer were highest. Throughout the year the surface was poorer in phosphate than the 0-50 metre layer. These variations were also reflected in the fluctuations of the phytoplankton populations.

Some relation was evident between the plankton abundance and the hydrological environment. The settled volumes were lowest during winter and highest in summer. Although zooplankton and phytoplankton were represented in the settled volumes, zooplankton mainly contributed to the volumes. During late spring when more nutrients, occasioned by increased upwelling, became available, a phytoplankton bloom occurred. This had the effect of providing food for the zooplankton which increased greatly, as was shown by the composition of the plankton in the subsequent summer season. The plankton volumes were lowest in winter when upwelling was reduced and the salinity and temperature of the 0-50 metre layer were relatively high.

Thus the environmental conditions in this area showed some evidence of a relationship between chemical, physical and planktological data. Nearer inshore in this area the environmental conditions were particularly favourable for the production and sustenance of plankton populations consisting of both zooplankton and phytoplankton.

(b) ROUTINE COASTAL AREA.

Because of the marked changes occurring at inshore stations at different times of the year, the available data from this area were treated on a seasonal basis. The only hydrological data

available were in the form of surface temperatures which were recorded usually three times every month at all stations. The data thus obtained were averaged and plotted on a seasonal basis. The settled volumes were obtained from catches taken with a horizontal net towed at the surface for ten minutes during daylight hours only. The average seasonal volumes of plankton for the individual stations were plotted together with the positions of commercial catches of pilchards. The seasonal occurrence of phytoplankton in the area was also plotted.

Few catches of pilchards were made during the summer season but maasbankers were caught in considerable numbers. Maasbanker-catch positions were therefore included for this season. No maasbanker catch data were available for the first three seasons of the year under review. From the examination of stomach contents it appeared that the food of the pilchard consisted mainly of phytoplankton while that of the maasbanker was mainly zooplankton.

The various factors affecting the routine coastal area, where commercial fishing takes place, are discussed below on a seasonal basis.

Autumn, 1950 (see Plate I, fig. 1 and Plate II).

Lowest settled volumes were found in two regions within the area—

- (a) in the south at Stations OO, NN and MM;
- (b) in the north at Stations AA, BB and EE.

Highest volumes were found in the middle of the area viz., at Stations JJ, HH and DD.

Fair quantities of phytoplankton were recorded at Stations JJ and OO during April and also at Stations OO during May. At the remainder of the stations zooplankton was dominant. The highest volumes of mixed plankton were obtained off Cape Deseada.

The surface-temperature chart (see Plate I, fig. 1) for this season reveals a regular belt of cold water running parallel with the coastline with a tongue which protrudes offshore between Cape Deseada and Lambert's Bay. The surface temperatures at Stations OO, II, KK, HH, GG, FF and JJ were all below 14° C. At Stations M, N and F which are all situated near the coast but within the area examined by R.S. *Africana II*, the average temperature was also less than 14° C. in autumn. It is noteworthy that at most of the stations situated within the tongue of colder water stretching to the west between Cape Deseada and Lambert's Bay, the highest plankton volumes

were recorded for this season. The temperatures at Stations AA, BB, CC, EE, LL, MM and NN were all above 14° C.

The commercial catch positions of pilchards were obtained from skippers of fishing vessels. (Commercial catch positions refer to the positions at which pilchard catches were made. Samples were taken from these positions for examination by the shore biologists). Although these positions were approximate, they gave an indication of the movements of fish within the area. During autumn twenty-six successful catches, from which samples were taken, were made in the Stompneus region, and twelve catches were obtained from the Lambert's Bay—Cape Deseada region. Three catches were made in the centre of the Bay. The majority of the catches were made in a region where settled volumes of plankton were low. It must be borne in mind, however, that unless a very heavy phytoplankton bloom occurred, the zooplankton always formed the main component of the volumes. The adult pilchards fed mainly on phytoplankton and for two months of this season phytoplankton was recorded in good quantities at Station OO in close proximity to the positions of these catches. Therefore, although the settled volumes were low, phytoplankton occurred in sufficient quantities to provide food for the pilchards. Catches of pilchards were also made near Station JJ where phytoplankton was recorded once during the autumn season. Some relationship between the feeding of the pilchard and the occurrence of phytoplankton was therefore evident during autumn.

It is of interest to note that the majority of the pilchard catches were made in the southern part of the routine coastal area, where the average temperature was just above 14° C. No catches were made in the region north of Lambert's Bay where the surface temperatures were all above 14° C.

Winter 1950 (see Plate I, fig 2 and Plate III).

The plankton distribution chart shows large settled volumes, gradually increasing from offshore towards the coast, and also increasing from Stompneus in the south to Lambert's Bay in the north. Particularly large volumes occurred off Cape Deseada and Lambert's Bay. With the exception of Stations OO and NN, all the stations yielded medium to high volumes. As was found in autumn, the region in the immediate vicinity of Stompneus once again yielded very low volumes. No phytoplankton was recorded in the region off Stompneus during this season. Good

quantities of phytoplankton were recorded during August at Stations GG, HH, II, JJ, KK and LL, all of which are situated close inshore.

The surface temperatures at all the inshore stations (including Stations M, N and P which are close to the coast, and also Stations L and Q) were lower in winter than in any other season. A belt of water with surface temperature below 14° C. occurred during winter (see Plate I, fig. 2). This belt of comparatively cool water followed a more regular pattern in winter than in autumn. Fifteen stations fell within this region, whilst at the remaining five the surface temperatures were above 14° C.

Very good pilchard catches were recorded during this season, the majority of which were made close inshore where the temperatures were lowest and plankton volumes highest. Sixty-one catches were made close inshore and eight in the region just north of Stompneus. The positions where pilchards were caught in winter were quite different from those of autumn. In autumn the main catching region was just north of Stompneus, whilst in winter the catches were made inshore north of the Berg River as far as Lambert's Bay. Few catches were made far offshore.

A probable factor causing the pilchards to be caught closer inshore in winter than in autumn may be the effect of the strong northwesterly winds, which blow during this season. The northwesterly wind tends to drive the surface water towards the shore and consequently the phytoplankton is also driven shorewards. Thus winter, when the surface temperatures were lowest and the settled volumes highest, was the best season for the pilchard fishery.

Spring 1950 (see Plate I, fig. 3, and Plate IV).

The distribution of the plankton in spring was completely different from that of winter. In contrast to the previous season the plankton volumes in spring were lower all round, the region close inshore yielded low volumes, and the only high concentrations occurred at Stations CC to DD, where the volumes increased in a westerly direction. Thus, whereas the volumes tended to increase towards the shore during winter, a complete reversal of this was evident during spring.

During September large quantities of phytoplankton were recorded at all the inshore stations. At five stations nearest to the coast, viz. FF, JJ, KK, LL and MM, phytoplankton occurred during October. Phytoplankton was recorded at MM throughout the season.

The surface temperatures also showed considerable differences from the previous season. The belt of cold water with temperatures below 14° C. narrowed considerably. It followed a very regular pattern parallel with the coastline and included Stations O, JJ and M only. With the narrowing of this cold water belt the influx of warm water towards the coast also became evident. Surface temperatures above 15° C. were recorded at Stations EE and II. The majority of the stations in this area were bounded by the isotherms 14° C. and 15° C.

Despite the overall increase in phytoplankton, only thirty-three catches of pilchards were made during this season. These catches were obtained fairly close inshore but none was made in close proximity to Lambert's Bay. The majority came from the region which extends from north of the Berg River, to just north of Cape Deseada. A few were made north of Stompneus.

This season, with more sunshine than in winter, not only had higher surface temperatures than the previous season but was also a good season for phytoplankton.

Summer 1950-1951 (see Plate I, fig. 4 and Plate V)

Settled volumes of plankton were again different from those of the other seasons. One of the two regions where high volumes occurred was in the close proximity of Stompneus; this was the first occurrence of high volumes in this region for the year. The other region was located close inshore between Lambert's Bay and Cape Deseada. Whilst high volumes occurred offshore during spring, they occurred inshore in summer, as was the case in winter. The stations located outside the regions where large volumes were found, yielded plankton volumes of medium size.

As in spring, summer was a very good season for phytoplankton. During December large concentrations of phytoplankton were registered at

the stations close inshore, viz. OO, NN, MM, LL, KK, JJ, FF and GG. In January good quantities of phytoplankton were found at all stations except CC and EE, whilst in February Stations EE, GG, HH, II, JJ, KK, LL, MM, NN, and OO all gave good recordings of phytoplankton. At Stations OO, NN, MM, LL, KK, JJ, and GG phytoplankton was found throughout the summer season, and it is interesting to note that they are all close inshore between Stompneus and Lambert's Bay.

Despite increased upwelling during late spring and early summer, solar radiation caused surface temperatures to be high in the summer season. The belt of water below 14° C. which was noticed in autumn, winter and spring was again apparent in summer. In spring and summer it was, however, narrow in width. The 15° C. and 16° C. isotherms now appear on the chart (see Plate I, fig. 4) indicating that an influx of warmer oceanic water had occurred. It is of interest to note that the phytoplankton mostly occurred where the temperatures were lower.

Only eight successful pilchard catches by the commercial boats, were sampled during this season, whilst thirty-two catches of maasbankers were investigated. During the summer season the pilchards moved away from the routine coastal area in a southerly direction, a movement probably connected with spawning activities. However, the later part of this season was a very good one for maasbankers. Most of the maasbanker catches were made in the vicinity of the inshore stations approximately on the line connecting Stompneus with Lambert's Bay where good quantities of phytoplankton and zooplankton were present.

The following table shows a seasonal comparison of pilchard catches with average settled volumes and surface temperatures for all stations in the routine coastal area.

TABLE II.

Season.	Pilchard Catches in Tons.	Settled Volumes in c.c. All Stations.	Surface Temperatures (°C.). All Stations.
Autumn, 1950.....	25,768	31.9	14.1
Winter, 1950.....	40,627	101.1	14.0
Spring, 1950.....	24,486	46.0	14.4
Summer, 1950-51.....	4,112	79.0	15.1

From Table II it is evident that during the winter season, when the temperature of the surface was lowest and the settled volumes were highest (mostly zooplanktonic in composition except for August when phytoplankton occurred in fair quantities) and particularly during the month of August (winter), more pilchards were caught than at any other time of the year. Both autumn and spring were very good seasons for pilchard fishing, and it is noteworthy that the settled volumes and surface temperatures were of the same order for these two seasons. The summer season of 1950-51 was a particularly poor one for pilchards. Considering the high settled volumes and the presence of good quantities of phytoplankton, it would seem that the higher surface temperatures in summer had something to do with the southerly migration of the pilchard shoals at this time of the year.

The following physical factors may contribute to the seasonal variations in surface temperature, plankton population and the number of pilchards caught commercially:—

(a) THE EFFECT OF SUNLIGHT.

During winter when solar radiation is reduced, surface temperatures are lowest, and zooplankton is abundant whilst phytoplankton appears only towards the end of the season. When the surface temperatures are lowest, more pilchards are caught than at any other time of the year. In spring and particularly in summer, when abundant sunshine causes the surface temperatures to reach a peak, the pilchard catches are poor, this being the time when the pilchards seem to start migrating southwards.

(b) WINDS AND CURRENTS.

The Benguela current flowing in a north-westerly direction, has a high content of nutrient salts. During late spring and early summer when strong southeasterly winds increase upwelling of cooler and nutrient-rich water, the temperature of the 0-50 metre layer decreases. The temperature of the surface itself, however, is higher in summer owing to the effect of increased absorption of solar radiation. The increased local upwelling results in heavy phytoplanktonic blooms, which sustain the rich zooplankton populations.

(c) THE INFLUX OF FRESH WATER FROM THE BERG RIVER.

The effect of the Berg River was particularly noticeable on the settled volumes of plankton, on

the salinity and on the positions where pilchards were caught. During the winter months when the river was in full flood, the plankton volumes were at their lowest in the southern part of St. Helena Bay. In summer when the flow of the river was greatly reduced the plankton volumes were highest near Stompneus Bay.

6. NIGHT SAMPLING STATIONS.

Night sampling stations were worked to determine whether a relationship existed between the feeding of the pilchard and maasbanker, and the occurrence of plankton organisms in waters where these fish were caught commercially. Whenever pilchards were not available, an effort was made to collect maasbanker samples. Unfortunately no samples of maasbankers were obtained during the year under discussion.

Stations were worked in the immediate vicinity of commercial boats in the act of brailing. The following procedure was adopted:—

- (i) Weather observations were made;
- (ii) a surface temperature was taken;
- (iii) a plankton haul was made with a N70 net towed at the surface for ten minutes;
- (iv) a representative sample of fish was collected from the catch of the commercial boat.

Table III on page 14 records the names of genera present in plankton catches and pilchard stomachs during the first three seasons of 1950. The average settled volumes of plankton tow-net catches at night stations, as well as the number of fish examined for their stomach contents, are also given. The letter c denotes the common occurrence of the particular genus, whilst the letter f applies when only a few individuals (± 5) of the genus occurred in fish stomachs. No data were available for the summer season of 1950-1951.

DISCUSSION.

Autumn 1950.—During this season zooplankton organisms were more abundant than phytoplankton organisms. The zooplankton consisted mainly of copepods, of which *Calanus*, *Centropages*, *Paracalanus* and *Metridia* were the commonest genera. *Coscinodiscus* and *Rhizosolenia* were the only common phytoplanktonic genera. The stomachs of pilchards examined (125 fish) contained mainly *Coscinodiscus* and *Rhizoso-*

TABLE III.

Season.	Plankton Hauls (N70H).		Average Settled Volumes in c.c.	Stomach Contents.		Number of Fish Examined.
	Zooplankton.	Phytoplankton.		Zooplankton.	Phytoplankton.	
Autumn, 1950.	<i>Calanus</i> c. <i>Centropages</i> c. <i>Paracalanus</i> c. <i>Metridia</i> c. <i>Oithona</i> . <i>Oikopleura</i> . <i>Sagitta</i> . Mollusc bivalves. Zoea crab larvae. <i>Peridinium</i> .	<i>Coscinodiscus</i> c. <i>Rhizosolenia</i> c.	74.8	<i>Calanus</i> f. <i>Centropages</i> f. <i>Metridia</i> f. Mollusc bivalves f. Digested remains of Copepods f.	<i>Coscinodiscus</i> c. <i>Rhizosolenia</i> c.	125
Winter, 1950.	<i>Centropages</i> c. <i>Calanus</i> c. <i>Paracalanus</i> c. <i>Oithona</i> c. <i>Metridia</i> c. <i>Acartia</i> f. <i>Sagitta</i> . <i>Oikopleura</i> . <i>Evadne</i> . <i>Goniaulax</i> . Zoea crab larvae. <i>Echinoplutei</i> . <i>Ophioplutei</i> . <i>Balanus cypris</i> . <i>Squilla</i> . Euphausiids. <i>Hydromedusa</i> . <i>Themisto</i> .	<i>Coscinodiscus</i> c. <i>Biddulphia</i> c. <i>Thalassiosira</i> . <i>Rhizosolenia</i> . <i>Chaetoceros</i> .	21.7	<i>Centropages</i> f. <i>Oithona</i> f. <i>Goniaulax</i> f. <i>Hydromedusa</i> f. <i>Orthoperidinium</i> f.	<i>Coscinodiscus</i> c. <i>Biddulphia</i> c. <i>Rhizosolenia</i> c. <i>Thalassiosira</i> c. <i>Chaetoceros</i> . <i>Guinardia</i> . <i>Asterionella</i> . <i>Nitzschia</i> .	175
Spring, 1950	<i>Calanus</i> c. <i>Centropages</i> c. <i>Paracalanus</i> c. <i>Oithona</i> c. <i>Metridia</i> . <i>Candacia</i> . <i>Evadne</i> . <i>Oikopleura</i> . <i>Themisto</i> . <i>Hydromedusa</i> . Larval <i>Polychaeta</i> . <i>Sagitta</i> . <i>Balanus cypris</i> larvae. <i>Goniaulax</i> . Zoea crab larvae. Dinoflagellates. <i>Jasus phyllsoma</i> larvae. <i>Peridinium</i> .	<i>Thalassiosira</i> c. <i>Chaetoceros</i> c. <i>Rhizosolenia</i> c. <i>Biddulphia</i> c. <i>Coscinodiscus</i> . <i>Nitzschia</i> . <i>Asterionella</i> . <i>Stephanopyxis</i> . <i>Eucampia</i> .	22.0	Dinoflagellates f. <i>Orthoperidinium</i> f. <i>Dinophysis</i> f.	<i>Thalassiosira</i> c. <i>Biddulphia</i> c. <i>Chaetoceros</i> c. <i>Rhizosolenia</i> c. <i>Guinardia</i> . <i>Nitzschia</i> . <i>Coscinodiscus</i> .	125

lenia. Small numbers of copepods and other zooplanktonic organisms were also present in the stomachs.

Winter 1950.—More night stations were worked during this season because more pilchards were available. Despite the fact that settled volumes were on the average lower than during the preceding season, more genera were present in the plankton catches. Zooplankton was again dominant, but phytoplankton was much more abundant than in the previous season.

Five genera of phytoplankton were commonly found in the plankton net catches, viz., *Coscinodiscus*, *Biddulphia*, *Rhizosolenia*, *Thalassiosira* and *Chaetoceros*. All of these were present in good quantities in the fish stomachs examined. Three other genera, not represented in the net catches of this season, were present in small numbers in fish stomachs. It is possible that these genera, *Nitzschia*, *Asterionella* and *Guinardia*, were present in the water layers below the depths at which the plankton nets were hauled. Small numbers of copepods and protozoons, as well as other zooplanktonic forms, were also found in the stomachs of the fish.

Spring 1950.—Numerous genera, both zooplanktonic and phytoplanktonic, were recorded during spring. Phytoplankton was more common than in the previous seasons and appeared in more or less the same quantity as the zooplankton. Similarly to the preceding seasons, copepods again formed the bulk of the zooplankton catches. The phytoplankton genera *Biddulphia*, *Rhizosolenia*, *Chaetoceros* and *Thalassiosira* were common in net catches, and were also present in very good quantities in the fish stomachs examined. More phytoplankton genera were caught in the plankton nets than were present in the stomachs of the 125 fish examined.

No traces of copepods or their remains were found in the stomachs, but a few genera of protozoons were present in small numbers. With more phytoplankton available during this season than during the previous seasons, the pilchards' diet was probably mainly phytoplanktonic in character at this time.

From the data for the first three seasons of 1950 it is evident that—

- (i) the food of the pilchard consisted mainly of phytoplankton;
- (ii) during autumn and winter when phytoplankton was not as plentiful as in spring,

small numbers of copepods and other zooplanktonic organisms were eaten;

- (iii) there was a relationship between the stomach contents of the pilchards and the composition of the phytoplankton obtained from the area where these pilchards were caught. It is probable that the location of large quantities of plant plankton within the commercial fishing area may serve as an indicator of the presence of feeding pilchards.

7. PLANKTON GENERA RECORDED DURING APRIL, 1950—MARCH, 1951.

The plankton catches obtained with the nets employed in this research yielded a great variety of organisms. The copepods represented by far the most important group in the zooplankton catches. The phytoplankton was represented by many genera and appeared in vast quantities at certain times of the year. In the research into the life histories of the pilchard and maasbanker the copepods and the phytoplankton are of major importance.

The phytoplankton not only sustained the rich copepod populations in the inshore waters of the West coast but also provided the main food for the pilchard, whilst the copepods were the main food source of the maasbanker.

(a) ZOOPLANKTON GENERA.

PROTOZOA.

<i>Tintinnus</i>	<i>Dinophysis</i>
<i>Noctiluca</i>	<i>Globigerina</i>
<i>Peridinium</i>	<i>Coelodendrum</i>
<i>Prorocentrum</i>	<i>Circoporus</i>
<i>Gymnodinium</i>	<i>Aulosphaera</i>
<i>Goniaulax</i>	<i>Sagenoscena</i>
<i>Ceratium</i> (2 species).	

COELENTERATA.

<i>Physalia</i>	<i>Cyanea</i>
<i>Velella</i>	<i>Lizzia</i>
<i>Diphyes</i>	<i>Beroë</i>
<i>Cubomedusa</i>	<i>Pleurobrachia</i>
<i>Aurelia</i>	

ANNELIDA.

<i>Terebella</i>	
Trochophores and larval stages—mainly of <i>Polychaeta</i> .	

ARTHROPODA.

CLADOCERA.

<i>Evadne</i>	<i>Podon</i>
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OSTRACODA.

Conchoecia

COPEPODA.

<i>Calanus</i> (5 species)	<i>Acartia</i>
<i>Calocalanus</i>	<i>Centropages</i>
<i>Paracalanus</i>	<i>Metridia</i>
<i>Microcalanus</i>	<i>Paracartia</i>
<i>Pseudocalanus</i>	<i>Pleuromamma</i>
<i>Rhincalanus</i> (2 species)	<i>Candacia</i>
<i>Eucalanus</i>	<i>Microsetella</i>
<i>Euchaeta</i>	<i>Oithona</i> (2 species)
<i>Aetideus</i>	<i>Oncaea</i>
<i>Scolecithricella</i>	<i>Sapphirina</i>
<i>Scolecithrix</i>	<i>Corycaeus</i>
<i>Gaetanus</i>	<i>Copilia</i> (2 species)

CIRRIPIEDIA.

Balanus nauplii and cyprids

AMPHIPODA.

<i>Hyperia</i>	<i>Gammarus</i>
<i>Phronima</i>	<i>Themisto</i>
<i>Oxycephalus</i>	<i>Parathemisto</i>
<i>Rhabdosoma</i>	

SCHIZOPODA.

<i>Euphausia</i>	<i>Thysanoessa</i>
<i>Nyctiphanes</i>	

DECAPODA.

<i>Sergestid</i> larvae	Megalopa and zoea crab larvae
<i>Pasiphaeid</i> juveniles	Phyllosomata and post pueruli of <i>Jasus</i>

STOMATOPODA.

Squilla

MOLLUSCA.

GASTROPODA.

<i>Pterotrachea</i>	<i>Carinaria</i>
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CEPHALOPODA.

<i>Sepia</i> juveniles	<i>Octopus</i> juveniles
<i>Loligo</i> juveniles	

PTEROPODA.

<i>Limacina</i>	<i>Cavolina</i>
<i>Clione</i>	<i>Echinospira</i> larvae
<i>Creseis</i>	

POLYZOA.

Cyphonautes larvae

ECHINODERMATA.

<i>Ophioplutei</i>	Post pluteus stages
<i>Echinoplutei</i>	

CHAETOGNATHA.

<i>Sagitta</i> (5 species)	<i>Eukrohnia</i>
<i>Spadella</i>	

TUNICATA.

<i>Oikopleura</i>	<i>Salpa</i>
<i>Pyrosoma</i>	<i>Doliolum</i>

Eggs and larvae of the following fish species:

<i>Sardinops ocellata</i>	<i>Lophius piscatorius</i>
<i>Trachurus trachurus</i>	<i>Trigla capensis</i>
<i>Engraulis capensis</i>	<i>Gaidropsarus capensis</i>
<i>Etrumeus micropus</i>	<i>Thyrssites atun</i>
<i>Merluccius capensis</i>	

Fig. 6 shows the seasonal variation in the abundance of important genera of the zooplankton caught in the N70V vertical nets in the routine offshore area.

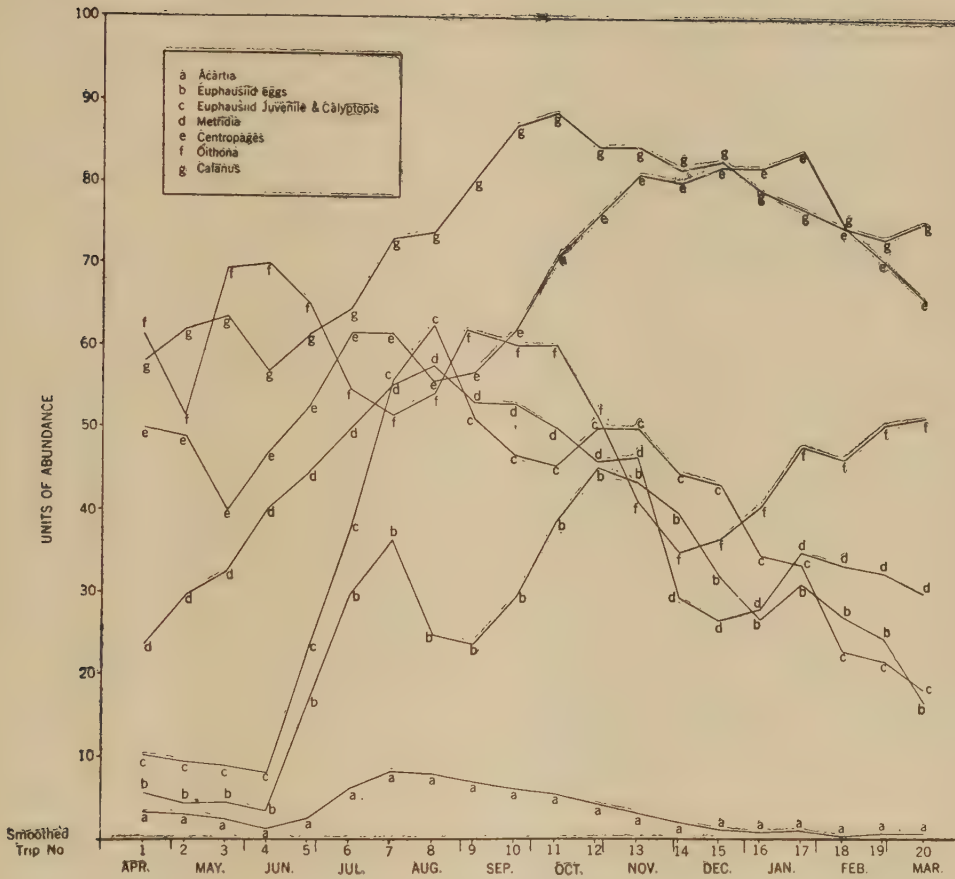
The number of individuals of each genus present in the catches is expressed as arbitrary units of relative abundance. The units were chosen in such a way that 25 individuals of the same genus in a total settled volume of 10 c.c. were recorded as CCC on the plankton log sheet. Similarly 20 individuals in 10 c.c. were recorded as CC, 15 as C, 10 as +, 5 as F, 2 as R. If the settled volume was greater or less than 10 c.c. the frequency of appearance of a genus was estimated on a direct proportional basis. For example the presence of 75 individuals in a settled volume of 30 c.c. was recorded as CCC.

From the sizes, of the settled volumes and these symbols the total numbers of individuals found during every trip were estimated. In order to present the seasonal variation in abundance in the form of a smooth graph these totals were averaged as follows:—

Assume that for consecutive trips the total numbers of individuals per trip were estimated at a, b, c, d, e, etc. Then the average was

$$\frac{a + b + c}{3} \text{ for the first trip, } \frac{b + c + d}{3}$$

$$\text{for the second, } \frac{c + d + e}{3} \text{ for the third etc.}$$



TEXT FIG. 6
SEASONAL VARIATION OF SOME IMPORTANT ZOOPLANKTON GENERA

Trigsurvey, 1954.

Government Printer, 1954

In this manner, excepting the totals for the first two and the last two, each trip was used three times in the smoothing process.

The following are short notes on the seasonal variation and distribution of the zooplankton genera shown in Fig. 6.

(a) *Acartia*.—This genus was never abundant, although a slight increase in numbers was evident during the winter season. The distribution of *Acartia* was mostly offshore, the highest numbers being recorded at Stations C, B, A and S.

(b) *Euphausiid* eggs.—The largest numbers of eggs were recorded during spring. Good quantities were also present in winter but there was a decline in their occurrence in summer and autumn. The majority of the eggs occurred at Stations D, E, F, I, S, T, G and H, whilst small numbers were present at the inshore stations nearest to the land.

(c) *Euphausiids*.—The juveniles, Calyptopis and Furcilia stages were present in greater numbers than the eggs of this group. Euphausiids were more abundant during winter than in any other season. The distribution of Euphausiids was widespread and particularly good catches were obtained at Stations T, S, A, B, C, D, E, F, G, H, I, J, K, Q and R. At Stations M, N and Q poor catches were obtained. The adult and juvenile stage were distributed more widely and also occurred in larger numbers than the eggs. The wider distribution and greater abundance of adult and juvenile stages might have been due to an influx of these stages from other areas.

(d) *Metridia*.—The numbers of this genus increased rapidly from autumn to winter and then decreased gradually from spring to summer. Large numbers of *Metridia* occurred at Stations H, I, O, Q, and L, which are all situated fairly close inshore. Good quantities were also recorded throughout the routine offshore area except at Stations T and S, where small numbers were found. It is of interest to note that the largest numbers were recorded at Stations H and Q, an area where upwelling was known to occur.

(e) *Centropages*.—This genus was present in large numbers throughout the year. Parti-

cularly large numbers were recorded during late spring and summer. The best catches were made at Stations D, E, F, G, H, I, J, K, L, M, N, O, Q and R, while the stations farthest from the coast such as T, S, A, B and C yielded much lower catches. *Centropages* were recorded on every occasion when the ship visited Stations I, J, K, O and L, all of which are situated near the commercial fishing grounds. Therefore this genus seems to be of importance as a food organism for the pilchard and maasbanker.

(f) *Oithona*.—During autumn and winter this genus was more abundant than in any other season. Fair numbers were recorded during spring, followed by a decline during summer and a gradual increase towards autumn of the next year.

Oithona was widely distributed throughout the routine offshore area, with the inshore Stations J, K, L, M, N, O, Q and R yielding the best catches.

(g) *Calanus*.—Various species of *Calanus* were recorded in large quantities throughout the year, especially in spring and summer. Similarly to *Oithona* the best catches of *Calanus* were made at the inshore Stations H, I, J, K, L, M, O, Q and R. Large numbers were encountered at all stations except the offshore Stations T, S, H, B and C. *Calanus* is an important food organism, and it is noteworthy that the highest numbers were recorded within the area of commercial fishing.

Generally speaking, when a bulky catch of zooplankton was made in inshore waters, such a catch consisted almost exclusively of two or three dominant genera. Catches made at the offshore stations usually contained no dominant genera but a much larger number of genera numerically of more or less equal strength.

The distribution of Salps and Doliolids encountered during the year is shown in Fig. 7. Mostly they occurred offshore, except during September, when they appeared in large numbers at Stations K, L, and M in the northern part of the area of investigation. Salps and Doliolids did not occur in the area where commercial fishing

took place. Fig. 7 also shows the limit of landward approach of oceanic *Foraminifera* encountered during November and December, 1950.

(b) PHYTOPLANKTON GENERA.

<i>Planktoniella</i>	<i>Thalassionema</i>
<i>Coscinodiscus</i>	<i>Pleurosigma</i>
<i>Rhizosolenia</i>	<i>Guinardia</i>
<i>Chaetoceros</i>	<i>Triceratium</i>
<i>Thalassiosira</i>	<i>Leptocylindrus</i>
<i>Nitzschia</i>	<i>Eucampia</i>
<i>Biddulphia</i>	<i>Fragilaria</i>
<i>Asterionella</i>	<i>Ditylum</i>
<i>Corethron</i>	<i>Melosira</i>
<i>Stephanopyxis</i>	

The seaward limits of heavy phytoplankton blooms which occurred during the year under discussion are shown in Fig. 7.

During September, 1950, a heavy outburst occurred in a limited area inshore. In December, January and February a particularly heavy bloom appeared over a greater area which covered nearly all the stations in the routine coastal area. Another widespread, heavy outburst occurred during March and April of 1951. These blooms all occurred within the area of commercial fishing, and when these phytoplankton populations are assessed, some indication of the general productivity of the area should emerge.

The following phytoplanktonic genera were dominant during the year:—

May, 1950:	<i>Coscinodiscus</i> and <i>Chaetoceros</i>
June, 1950:	Phytoplankton very sparse
July, 1950:	Phytoplankton very sparse
August, 1950:	<i>Chaetoceros</i>
September, 1950:	<i>Rhizosolenia</i>
October, 1950::	No recording
November, 1950:	<i>Thalassiosira</i> and <i>Chaetoceros</i>
December, 1950:	<i>Chaetoceros</i>
January, 1951:	<i>Coscinodiscus</i> and <i>Chaetoceros</i>
February, 1951:	<i>Coscinodiscus</i>

Coscinodiscus and *Chaetoceros* were more abundant than any other phytoplanktonic genera.

8. CLUPEOID EGGS.

In the commercial fishing area for pilchards and maasbankers the physical and chemical factors controlling the environment were favourable for the growth of phytoplankton, and hence for a rich zooplankton population.

Small numbers of clupeoid and other fish eggs were recorded from time to time in the usual plankton catches. An attempt was made to ascertain which plankton organisms occurred in association with clupeoid eggs, when large numbers of the latter were found. The range of the surface water temperature affected the occurrence of eggs, and it seemed as if spawning took place to a greater extent at the higher limits of the temperature range. Davies (1954) found that in 1950-51 pilchard ova were present in surface water, the temperature of which ranged from 12.8° to 20.0° C.

It also appeared that when spawning occurred at the lower limits of the temperature range, more organisms were found in association with the eggs. The following organisms appeared with eggs at the lower and higher limits of the temperature range, respectively.

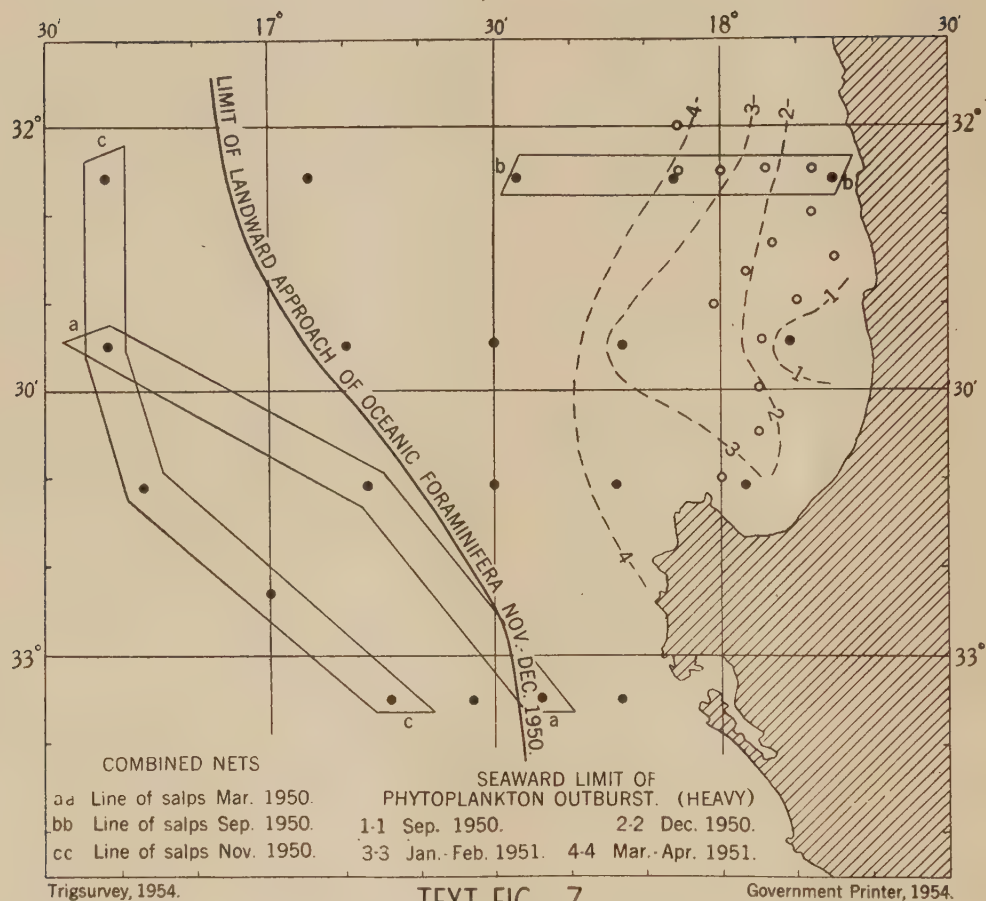
Lower Limit of Temperature Range.	Higher Limit of Temperature Range.
<i>Chaetognatha</i> (<i>Sagitta</i>). Euphausiids. Copepoda (<i>Eucalanus</i>). Megalopa crab larvae.	Hydromedusae. Salps and Doliolids. Megalopa crab larvae.

These data are not conclusive because eggs were never found in large numbers during the year.

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TEXT FIG. 7
PLANKTON DISTRIBUTION CHART.

paper, Dr. A. J. Clowes, Senior Hydrologist, for assistance with hydrological data and criticism, Mr. D. H. Davies, Senior Biologist, for constant enthusiastic help, guidance and criticism, and Mr. D. J. van Schoor, Assistant Biologist, for helping with the extraction of data.

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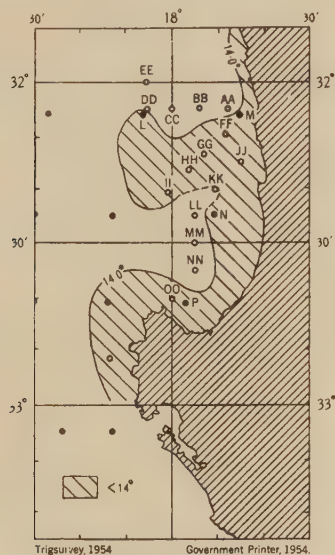


PLATE 1 FIG. 1
AVERAGE SURFACE TEMPERATURES, ROUTINE
COASTAL AREA AUTUMN 1950

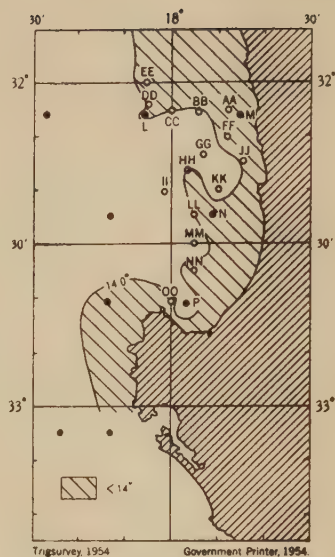


PLATE 1 FIG. 2
AVERAGE SURFACE TEMPERATURES, ROUTINE
COASTAL AREA WINTER 1950

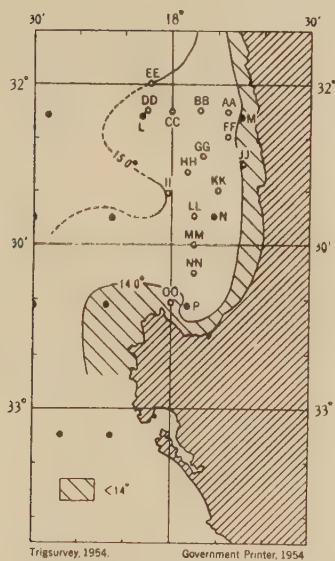


PLATE 1 FIG. 3
AVERAGE SURFACE TEMPERATURES, ROUTINE
COASTAL AREA SPRING 1950

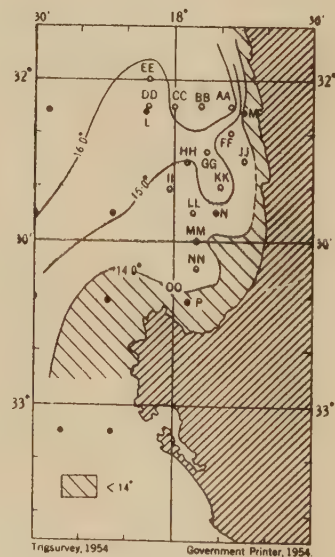


PLATE 1 FIG. 4
AVERAGE SURFACE TEMPERATURES, ROUTINE
COASTAL AREA SUMMER 1950

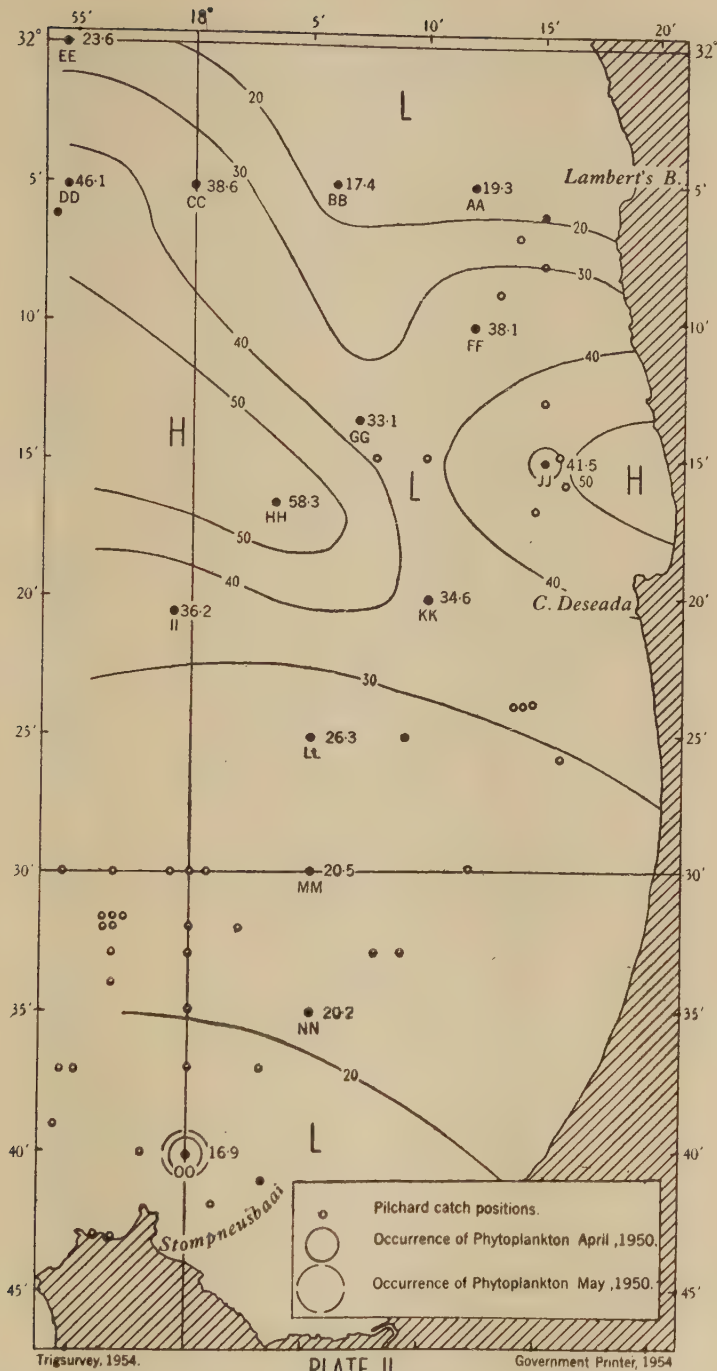
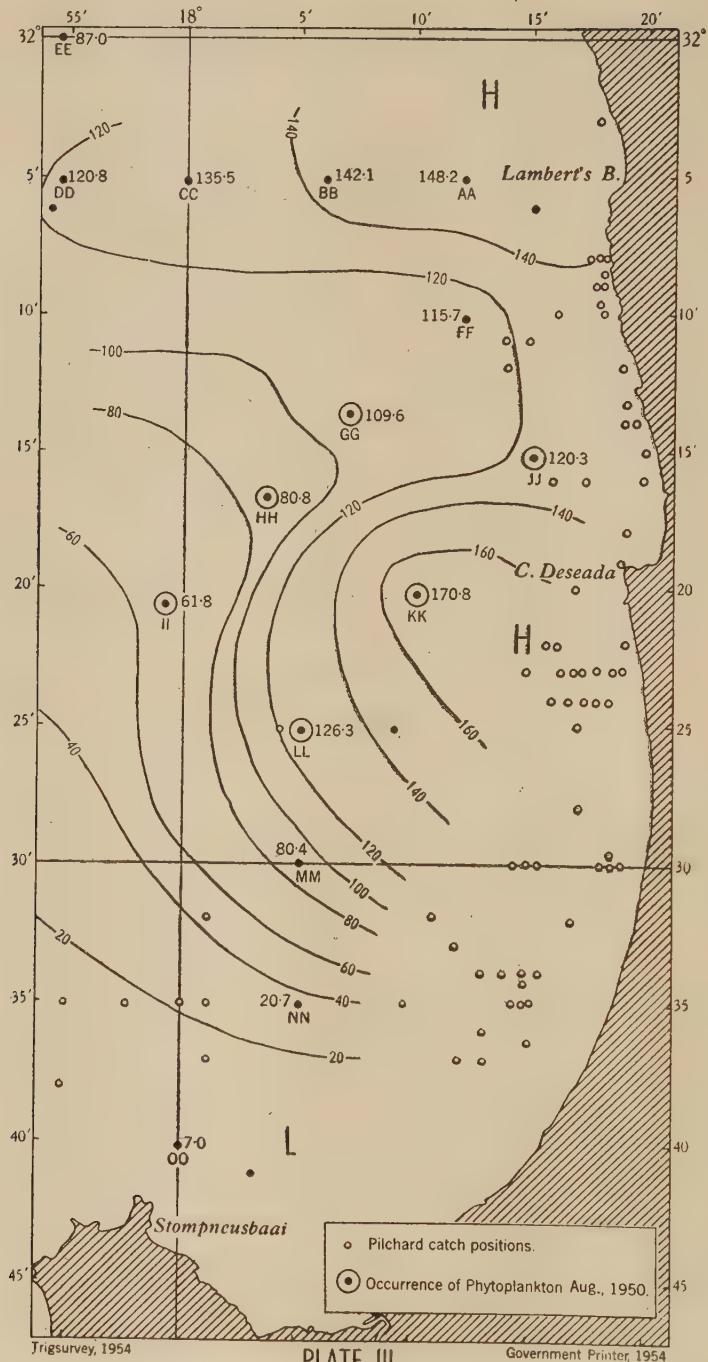


PLATE II
AVERAGE SETTLED VOLUMES, ROUTINE COASTAL AREA
AUTUMN 1950



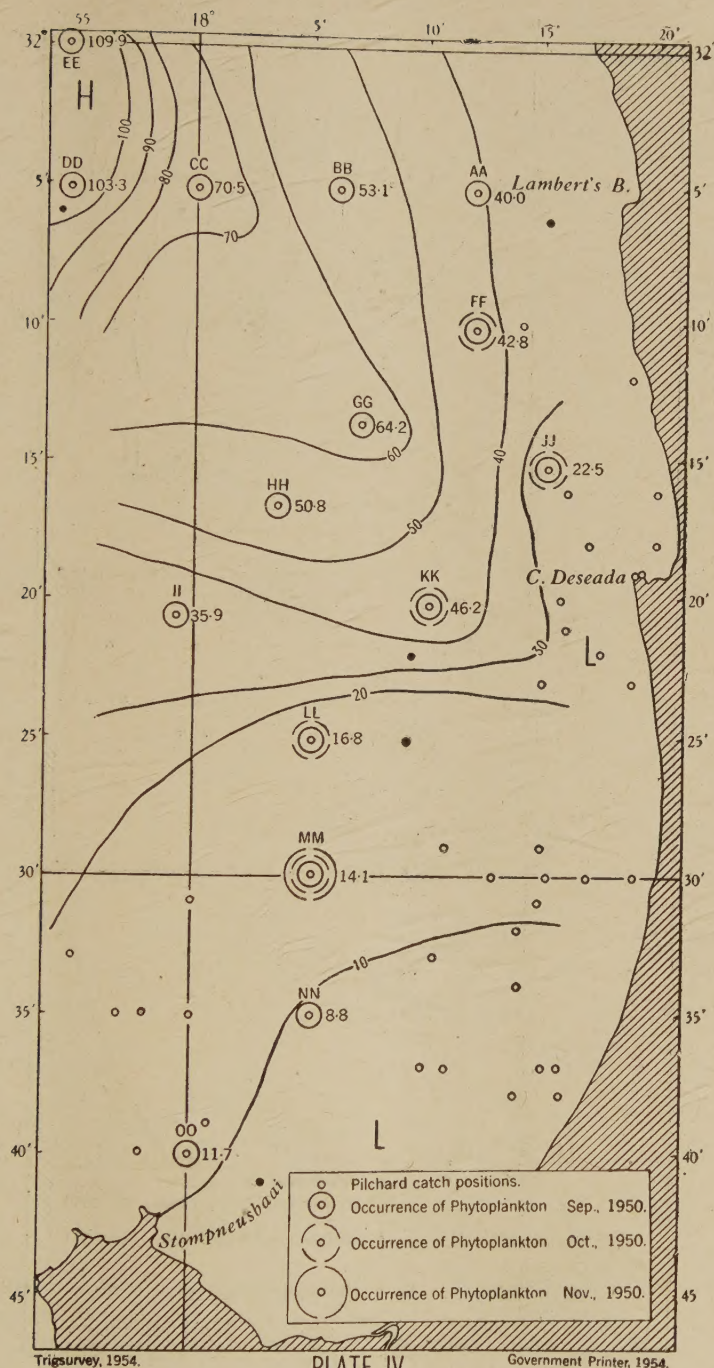


PLATE IV
AVERAGE SETTLED VOLUMES, ROUTINE COASTAL AREA.
SPRING 1950

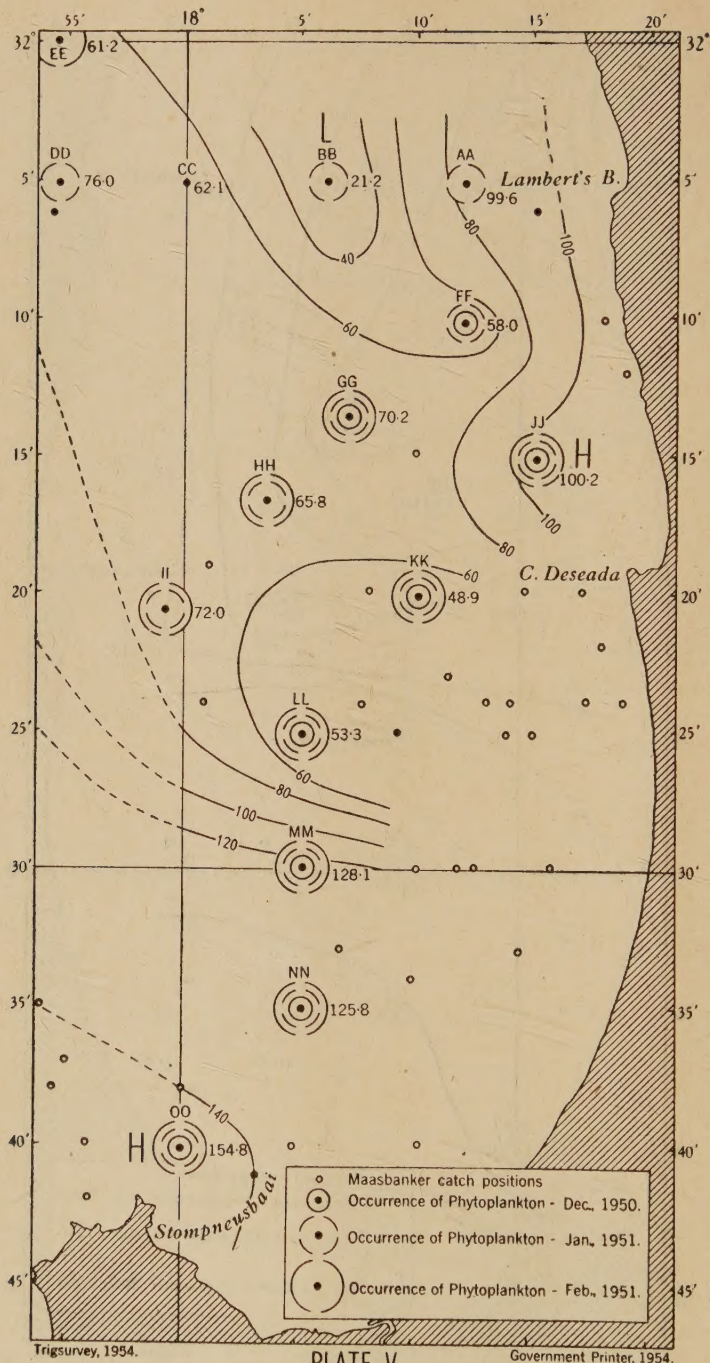


PLATE V
AVERAGE SETTLED VOLUMES, ROUTINE COASTAL AREA.
SUMMER 1950-1951

